Radius of an electron.

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It is interesting to consider the question of the electron radius. It can be shown that the exact radius of any elementary particle (photon, quark, etc.), including the electron, is equal to zero. This is exactly and strict.

It is important to note that the radius of the electron, like any other elementary particle, does not strive for zero, namely, strictly equal to zero.

Recall that according to the theory of relativity, all elementary particles must be considered as point objects. That is, objects that, by definition, have no size. In the textbook L. Landau and E. Lifshitsa “Field Theory” shows [1] that “...the theory of relativity makes the existence of absolutely solid bodies absolutely impossible...”.

If an elementary particle had a certain size (radius and other similar classical characteristics), then it is obvious that such a particle should be absolutely solid. But, the deformation of the particle means the theoretical possibility of its destruction and the possibility of independent movement of individual parts of the particle, which means that such a particle can no longer be considered elementary.

Here is a quote from the textbook [1]:

“...Thus, we arrive at the result that when the disk rotates, the ratio of its circumference to the radius (measured by a stationary observer) should change instead of remaining equal to 2π. The contradiction of this result with the assumption made shows that in reality the disc cannot be absolutely rigid and during rotation it inevitably undergoes some complex deformation, depending on the elastic properties of the material from which the disc is made.

The impossibility of the existence of absolutely rigid bodies can be convinced in another way. Let some solid body be set in motion by an external action at some point of it. If the body were absolutely solid, then all its points would have to move simultaneously with the one that was affected; otherwise, the body would be deformed. The theory of relativity, however, makes this impossible, since the impact from a given point to the rest is transmitted at a finite speed, and therefore all points of the body cannot simultaneously begin to move.

From what has been said, certain conclusions follow regarding the consideration of elementary particles, that is, particles for which we believe that their mechanical state is fully described by specifying three coordinates and three components of the speed of movement as a whole.

Obviously, if an elementary particle had finite dimensions, that is, would be extended, then it could not deform, since the concept of deformation is associated with the possibility of independent movement of individual parts of the body. But, as we have just seen, the theory of relativity shows the impossibility of the existence of absolutely rigid bodies.

Thus, in classical (non-quantum) relativistic mechanics, particles that we consider as elementary cannot be ascribed to finite sizes. In other words, within the limits of the classical theory, elementary particles should be considered as point...”.

In addition, according to the principle of Heisenberg in quantum mechanics, particles do not have a trajectory by definition. Since according to the Copenhagen interpretation, the state of the elementary particle determines its subsequent state not unambiguously, but only with a certain probability.

That is, the position of the microparticles inside the de Broglie waves is determined by statistical determinism (quantum effects are manifested precisely inside the waves of de Broglie).

Based on the principle of Heisenberg, the exact definition of the particle coordinates will mean the complete uncertainty of its impulse.

$$\Delta x * \Delta p \geq \hbar / 2$$

$$\Delta p \geq \hbar / (2 * \Delta x)$$

$$\Delta x = 0 \quad \rightarrow \quad \Delta p = \infty$$

But, the fact is that the “waves of matter”, that is, the waves of de Broglie, have their own minimum size - this is the compton’s wavelength for a specific elementary particle, since the particle speed cannot exceed the speed of light in vacuum.

$$\lambda = h / (m * v)$$

$$v \rightarrow c$$

$$\lambda c. = h / (m * c)$$

Therefore, we will not be able to have the exact coordinate of the particle, we will only have a probabilistic description inside the de Broglie waves (according to the corpuscular-wave dualism). This is a consequence of the fact that the elementary particle has no size, but is a strictly point object. If the particle had a length in space, then this would also mean the presence of a trajectory.

It should be noted that inside the Compton wave, the minimum error in measuring the particle coordinate (Δx) corresponds to the momentum uncertainty (m*c), which corresponds to the minimum energy for the formation of a particle-antiparticle pair, and then the measurement process itself loses its meaning. That is,

inside the Compton wave we can no longer consider an elementary particle even as a point object - only as a wave.

The fact that the elementary particle has a radius equal to zero can easily be understood if you bring an analogy with a mass of rest of the photon.

The photon can move only at the speed of light, and the mass of rest of the photon is strictly zero. If we could somehow stop the photon (when v=0), then its mass of rest could exist and be measured. But the photon moves only at the speed of light and therefore has no rest mass.

Similarly with the radius of an elementary particle: if we could somehow have the exact coordinates of the particle and, consequently, the trajectory (and not a probabilistic description inside the de Broglie waves), then the particle would also have a certain size in space. But, since the elementary particle does not have a trajectory, but is described only by statistical determinism, its radius is strictly equal to zero.

Thus, during experimental measurement of the electron radius, it will always be fixed that the electron radius is less than the accuracy of the device. Naturally, all elementary particles will behave similarly when measuring their radius.

Consequently, if we are able to experimentally measure the radius, extent, and similar characteristics of any particle, then we can safely say that this particle is not elementary.

1. Landau L. D., Lifshits E. M. Theoretical physics. Volume 2. Theory of the field. Moscow: Nauka, 1988. P. 67 – 69.